

COMPARISON OF JET AIRCRAFT AND TIROS IV VIEWS OF DENSITY AND ORGANIZATION OF CLOUDS

EDWARD L. HONODEL

U.S. Weather Bureau, Honolulu, Hawaii

ABSTRACT

Cloud pictures taken from jet aircraft flying at approximately 30,000 ft. are compared with pictures taken at the same time by TIROS IV. Comparison is also made with sea level and upper air charts. The study suggests that a catalog of simultaneous TIROS and aircraft pictures would be of value to pilots and meteorologists for flight planning and preparing terminal forecasts.

1. INTRODUCTION

From examination of the first TIROS I cloud photographs it became apparent that a new type of weather information was being made available to the meteorologist. He was now being given two sets of information: one taken by the human observer from the surface with horizontal limits restricted to 30 to 40 mi.; the other from TIROS satellites with a radius of view, say, 350 mi. The wide-angle lens on TIROS IV, launched on February 8, 1962, provided a field of view approximately 450 mi. square when the optic axis was normal to the earth's surface [1].

Because an order of magnitude separates the areas viewed by the ground-based observer and by TIROS satellites it is important for the meteorologist to relate one to the other. Few studies relating these two are available. Conover's [2] recent study is one of the few.

The purpose of this paper is to compare cloud pictures taken from TIROS IV with those taken simultaneously from jet aircraft, and to identify, where possible, mesoscale structures such as patterns, texture, and image shapes of principal cloud forms.

2. DISCUSSION OF PHOTOGRAPHS

On May 26, 1962, the author had the opportunity to make a jet flight from Honolulu to San Francisco and return the following day, May 27. On these days the TIROS IV weather satellite was viewing the Pacific near the Hawaiian Islands. The opportunity thus arose to compare directly cloud pictures taken from the aircraft with those from TIROS IV over the same area at the same time. It was hoped that this subjective comparison would shed some light on the question: "What are we looking at when we examine TIROS cloud pictures?"

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Pictures (35-mm. color slides) were taken over the route from Honolulu to San Francisco at 5-min. intervals.

For the present comparison the slides for only the first segment (Honolulu to 30° N., 145° W.) are used. Figure 1 shows the aircraft track, picture sequence, approximate camera angle, and the area studied on the outward flight. It can be readily determined that the distance to the

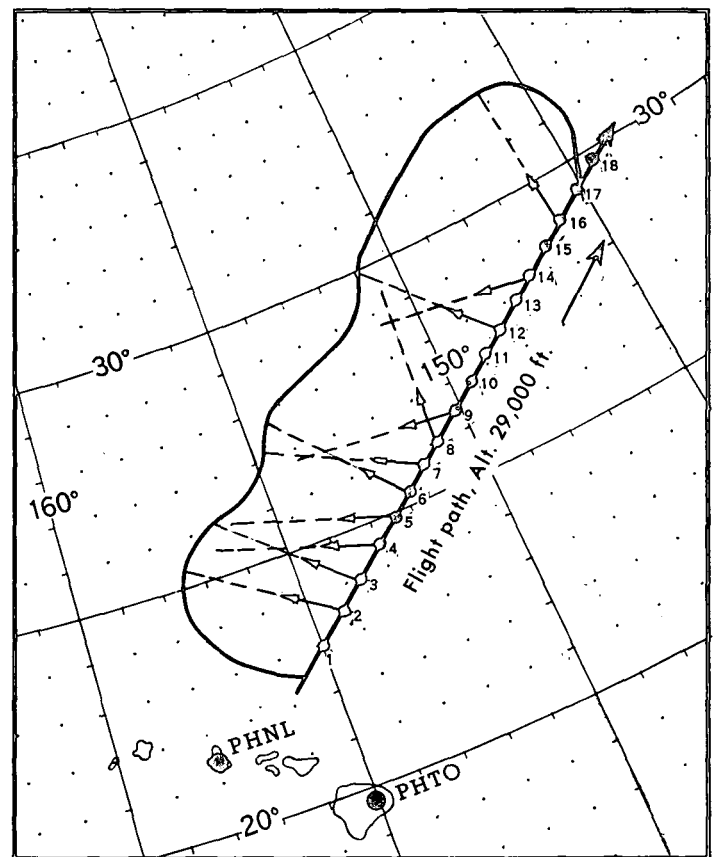


FIGURE 1.—Approximate area covered by photographs and picture angles from jet aircraft Honolulu to San Francisco May 26, 1962. Frame 2 was taken at 0014 GMT May 26 and subsequent frames at 5-min. intervals.

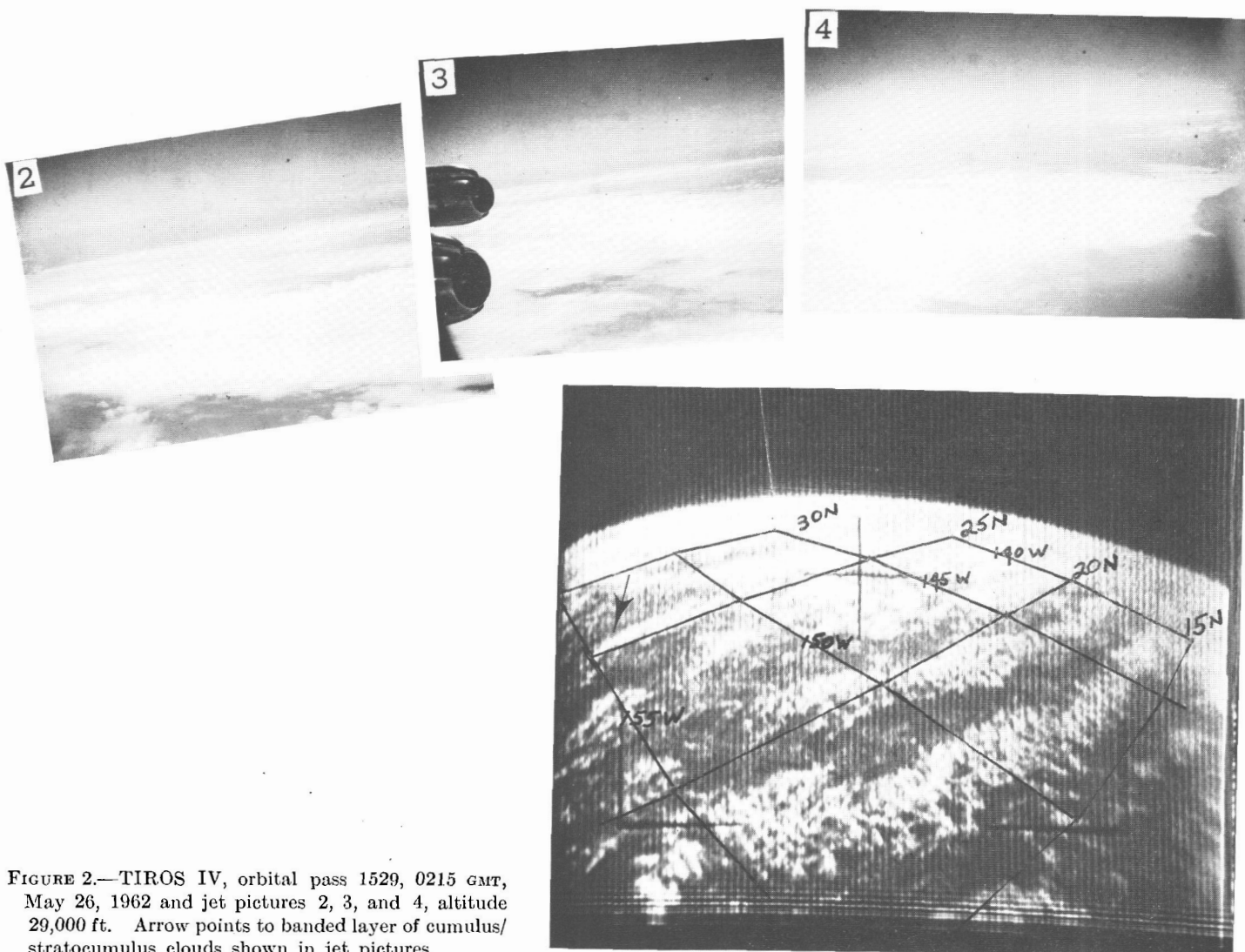


FIGURE 2.—TIROS IV, orbital pass 1529, 0215 GMT, May 26, 1962 and jet pictures 2, 3, and 4, altitude 29,000 ft. Arrow points to banded layer of cumulus/stratocumulus clouds shown in jet pictures.

horizon viewed from an aircraft at an altitude of about 30,000 ft. is on the order of 200 mi. This 200-mi. limit outlines the picture area viewed in figure 1. However, when viewed from this altitude, cloud features near the horizon are so compressed in a small section of the photograph that only the largest features are recognizable; therefore, arrowheads (fig. 1) show approximately the center of the area shown on the 35-mm. photographs.

Each camera view in the horizontal subtends a lens angle of 40° ; thus, with known distance to the horizon and known angle of view, computations indicate each 35-mm. frame views a section of the earth which is 144 mi. wide at the horizon.

Time of the TIROS picture series was 0215 GMT May 26, 1962, orbital pass 1529; time of the cloud pictures from the aircraft was 0014 to 0124 GMT May 26, 1962.

Cloud forms over the first portion of the route were for the most part cumulus/stratocumulus combinations with occasional cumulus of slight or possibly moderate vertical

extent. Figure 2 shows a TIROS view at a rather large nadir angle with the camera's principal point near the horizon. Near the left edge (arrow) an east to west oriented band of clouds is discernible along 25° N. Pictures 2, 3, and 4 show what this cloud band looked like from the aircraft. The edge of the same cloud band is also seen in the TIROS picture of figure 3 (arrow near left edge). From picture dimensions previously discussed it was estimated that this band of clouds was about 55 mi. wide.

Pictures 5 and 6 in figure 3 show a change from the broken stratiform clouds of figure 2 to scattered fair-weather cumulus clouds. The areas of pictures 5 and 6 correspond to the circled area on the TIROS photograph (fig. 3). These fair-weather cumulus cells were relatively small, their estimated diameter being on the order of one-half to one mile. They were therefore, smaller than the TIROS IV wide-angle TV raster line width which is about 2 miles when normal to the earth, and thus they cannot

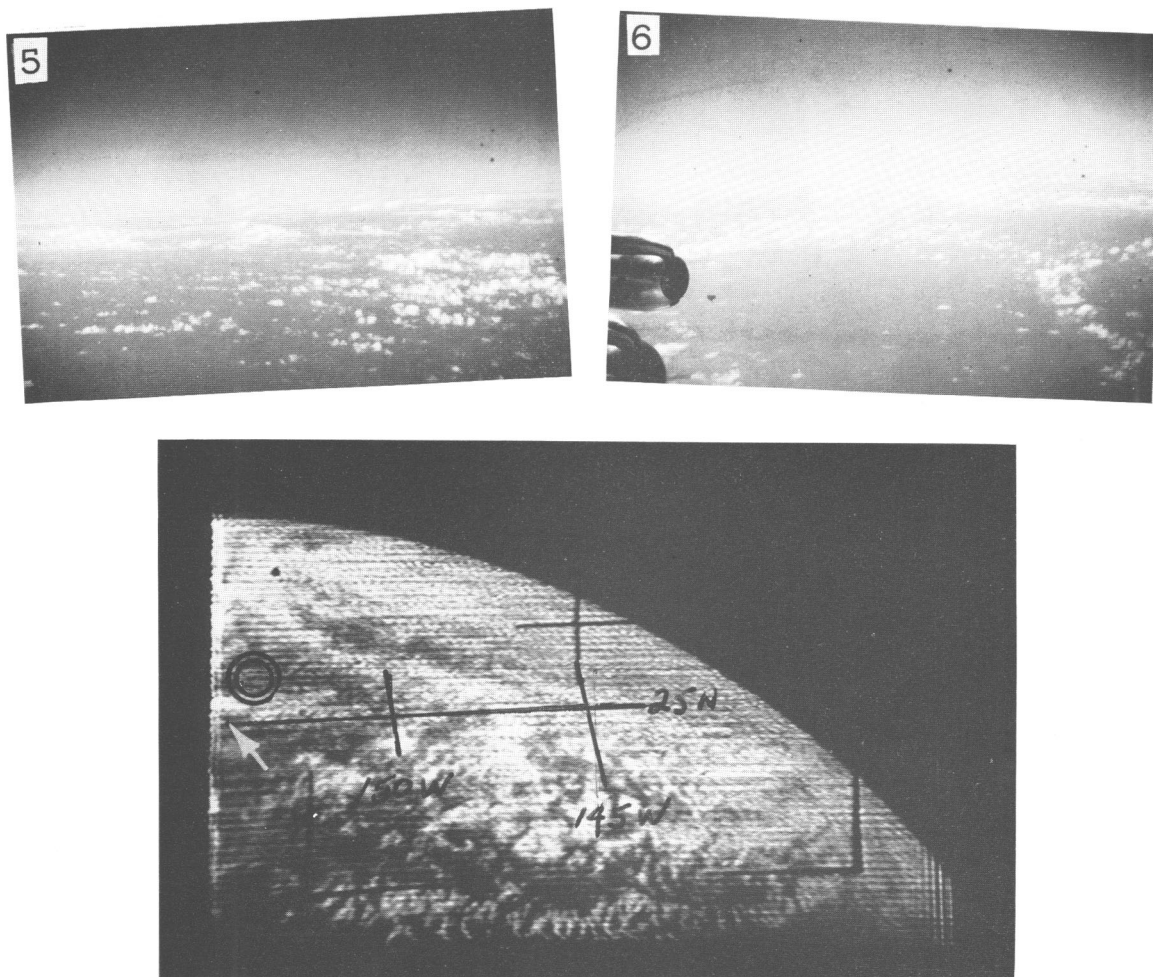


FIGURE 3.—TIROS IV, orbital pass 1529, 0215 GMT, May 26, 1962 and jet pictures 5 and 6, altitude 29,000 ft. Arrow points to banded layer of cumulus/stratocumulus clouds noted in figure 3; circle shows region of scattered fair-weather cumulus clouds as shown by jet pictures 5 and 6.

be individually resolved in the TIROS wide-angle pictures [3]. However, the combined effect of the unresolved cumulus would be to add to the overall gray tone.

The arrow on the TIROS photograph, figure 4, points to about the center area viewed in the accompanying pictures 7, 8, and 9. Picture 8 shows a view looking northward along 151° W., over a broken to overcast layer of stratocumulus and cumulus with possible patches of altocumulus, into a scattered cloud area near the horizon. This seems to agree favorably with the same area viewed by TIROS IV. From picture 8 one may also note the alignment of clouds with the trade wind flow pattern, in this instance, from upper right to lower left. The 0000 GMT surface map of this date, figure 5, indicates a 15- to 20-kt. surface trade wind flow with a deep trade layer extending to the 500-mb. level, figure 6. Malkus et al. [4], through the use of aerial photography, have shown that cumulus cloud patterns paralleling the low-level streamlines are common in the tropical Pacific.

This "parallel mode," according to the authors, is usually composed of small clouds closely spaced.

In figure 7 the arrows on TIROS photograph A show the approximate position of pictures 12, 14, and 16. The arrow shafts are oriented with the camera angles, and arrow tips point toward the center of the 35-mm. pictures. It is of interest to note that even though A is a wide-angle picture a good correspondence is discernible between the scattered clouds seen on it and those seen in pictures 12 and 14. The circled area on TIROS photograph B (fig. 7) again shows the general area viewed by pictures 12 and 14.

A point of interest on TIROS photograph A is the cellular structure or polygonal shape of the cloud cells just north and west of the center arrow marking picture 14. Krueger and Fritz [5] found this type of cellular pattern to exist under a subsidence inversion with a superimposed layer of greater stability which serves to inhibit convection. Picture 14 bears out this stable

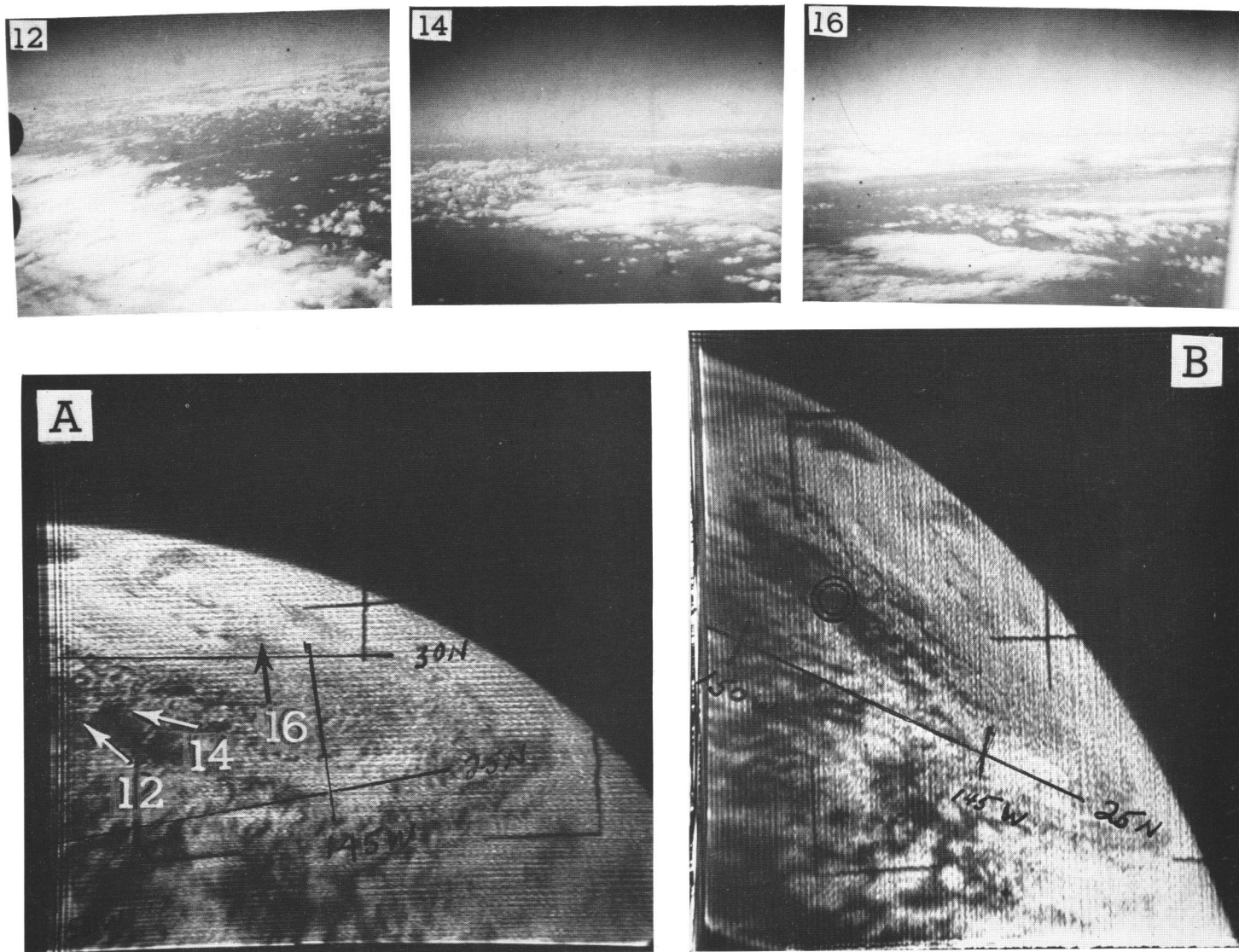


FIGURE 7.—TIROS IV, orbital pass 1529, 0215 GMT, May 26, 1962 and jet pictures 12, 14, and 16, altitude 29,000 ft. Numbered arrows on "A" show the approximate area viewed and camera angle of corresponding jet pictures with reference to flight path. Circled area on "B" corresponds to the scattered clouds viewed in jet pictures 12 and 14.

Looking again at the synoptic data for this date, figures 5, 6 and 8, we see a subtropical upper-level Low south of the flight path. The next section will cover the return flight looking south toward and into this upper-level system.

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The pictures taken on the return trip, San Francisco to Honolulu, May 27, 1962, deal with the same general area from 29° N., 147° W. to Honolulu. Figure 9 depicts the approximate field of view at 31,000 ft. and camera angle for selected pictures. Time of the TIROS series was 0139 GMT, May 27, 1962, orbital pass 1543; time of the cloud pictures 2359 to 0117 GMT, May 26 to 27, 1962.

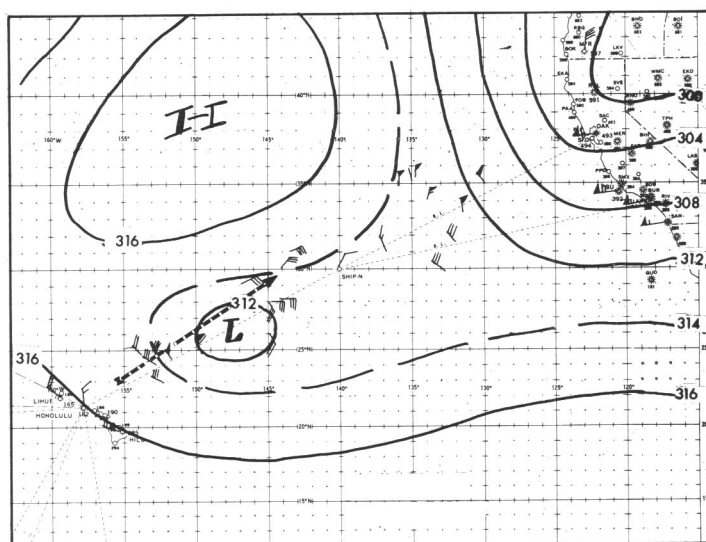


FIGURE 8.—300-mb. chart, 0000 GMT, May 26, 1962.

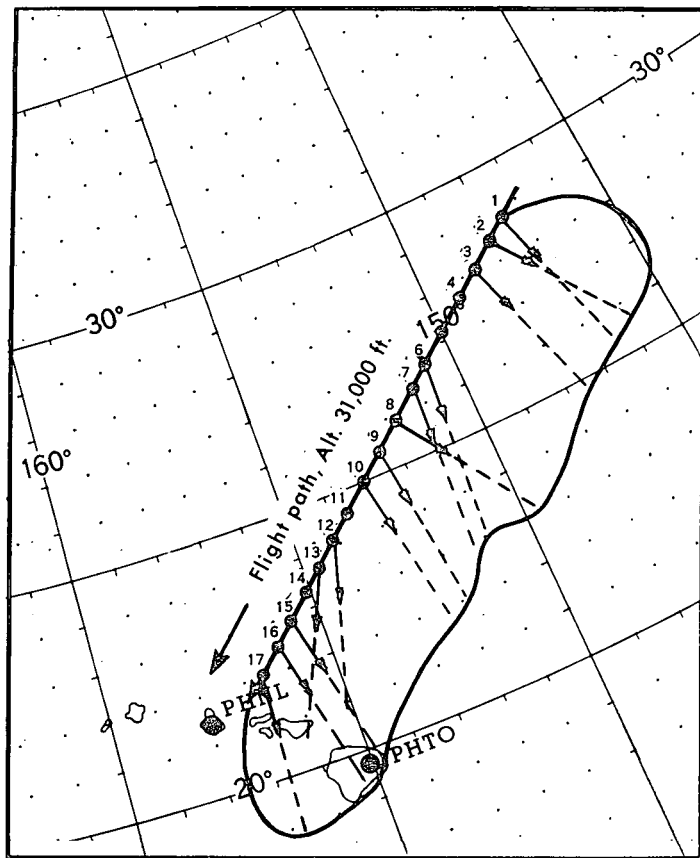


FIGURE 9.—Approximate area covered by photographs and picture angles from jet aircraft San Francisco to Honolulu May 27, 1962. Frame 1 was taken at 2359 GMT, May 26, subsequent frames at 5-min. intervals.

The TIROS photograph, figure 10, shows the flight path (long arrow). The area A on the photograph, about 26° N., 146° W., indicates a cloud mass that appears slightly brighter than those in the surrounding area. This bright area was near the center of the upper-level Low (fig. 11), that had remained in about the same position for the past 24 hr. Pictures 1, 2, and 3 (fig. 10), looking south toward the center and south side of this upper Low, show the thick cirrus layer on the horizon. We surmise then that the brightness in area A is due to a combination of cirrus overlying a low-level scattered to broken cumulus and stratocumulus layer. We might further assume, looking at the same TIROS photograph, that the banded bright area of clouds oriented nearly east to west along 22° N. is also made up of cirrus overlying a lower cumulus and stratocumulus cloud deck.

Clouds and weather systems associated with subtropical upper troughs have received only limited study in the past mainly because these systems are confined to data-sparse oceanic regions. Recent surveillance by the TIROS satellites affords the opportunity to study these upper-level systems, but caution must be exercised in distinguishing between upper and lower tropospheric vortices. Sadler [7] mentions that a preliminary study of

the TIROS III data over the central Pacific indicates the upper vortices can be identified from photographs and that under most circumstances they can be distinguished and separated from the low-level vortices. However, the satellite photographs alone are not sufficient but must be used in conjunction with tropical synoptic charts and a knowledge of the regional climatology.

The TIROS photograph, figure 12, is near the fringe area of poor resolution but the general cloud patterns show some alignment with the surface trade flow. The surface high pressure, as on the preceding day, was firmly entrenched with a strong "omega" block over the eastern Pacific, figures 13 and 14. The flight path (long arrow) was through the southern portion of this High and well above all clouds, and the only cirrus noted was that discussed in the previous section. Pictures 6 through 10 (fig. 12), were taken looking south and generally show a scattered to broken cloud layer. Pictures 9 and 10 are noted on the TIROS photograph by the short arrow and show the banded cloud structure with occasional towering cumulus imbedded in these bands. Surface ship reports in this area indicate broken cumulus and cumulus development; however, pictures 9 and 10, taken at 30,000 ft. indicate what well may be an altocumulus layer. This assumption is based on the apparent contiguity of clouds to flight level, on the report of middle clouds (code 6) made by a surface ship in this region, and on a weak inversion from 19,000 to 20,000 ft. noted on the sounding for this date at Lihue, Kauai, 250 mi. to the southwest.

Pictures 12, 13, and 14 (fig. 15) were taken at a minimum angle to the flight path looking out from the pilot compartment and view a general scattered area of fair-weather cumulus clouds. The pilot estimated the tops to range from 8,000 to 10,000 ft. The circled area in the TIROS photograph in figure 15, shows the area viewed as a general gray area which indicates, again, these fair-weather cumulus clouds were not of sufficient diameter to be resolved individually but, nonetheless, add to the overall gray tone.

The last portion of the flight, descending over the Hawaiian chain, (fig. 16), views fair-weather cumulus clouds very noticeably parallel to the prevailing trade wind flow. These pictures seem to be compatible with the circled area in the TIROS photograph in that these clouds are too small to be resolved. On the horizon just southeast and over the island of Hawaii, pictures 15 and 16, some large towering cumulus clouds are visible. This is in good agreement with the bright cloud area in the accompanying TIROS photograph (arrow) surrounding the island. A very thin cirrus layer may also be seen, adding perhaps to the overall brightness.

3. DISCUSSION OF PROBLEMS

The reflectivity of cloud images was excluded from this study although this is certainly important for proper interpretation since atmospheric illumination and camera and sun angles are necessary factors for determining the

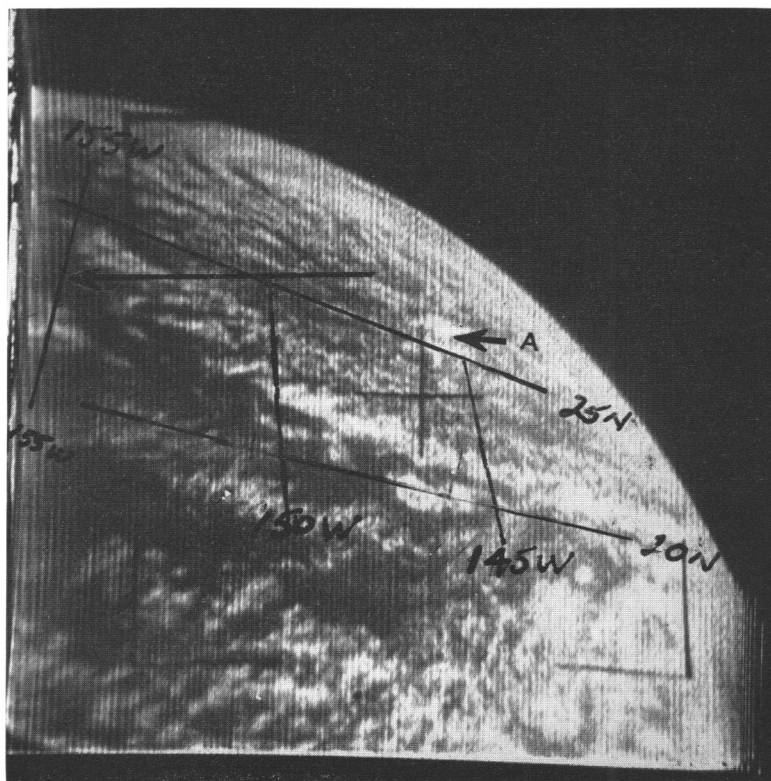


FIGURE 10.—TIROS IV, orbital pass 1543, 0139 GMT, May 27, 1962 and jet pictures 1, 2, and 3, altitude 31,000 ft. Long arrow depicts flight path, short arrow points to area A, a cloud mass brighter than the surrounding region. The accompanying jet pictures show this area.

degree of brightness of cloud forms. Conover [2] determined that water clouds always appear brighter than ice clouds of the same thickness under the same degree of illumination; also that most cirrus and cirrostratus without underlying clouds are translucent, and, when reported as "scattered" by ground observers, they are invisible to the satellite except under conditions of strong illumination and dark background.

Very little is said in this study about altocumulus or altostratus clouds. This is due mainly to the fact that it is difficult, to say the least, to distinguish between low and middle clouds from jet altitudes and experienced pilots have mentioned this fact to the author. How then may we determine middle cloudiness from TIROS images when we cannot determine them precisely from jet altitudes? This should certainly be the subject of investigation and research since we must know what we are looking at before direct comparison can be made between satellite pictures and sky conditions.

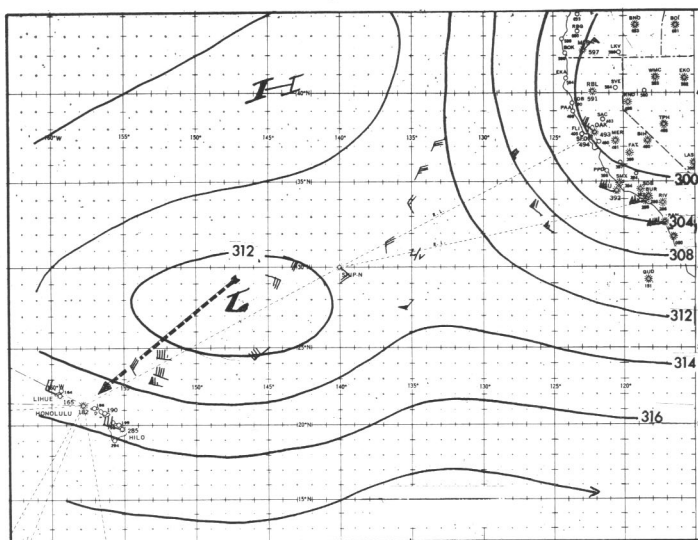


FIGURE 11.—300-mb. chart, 0000 GMT, May 27, 1962.

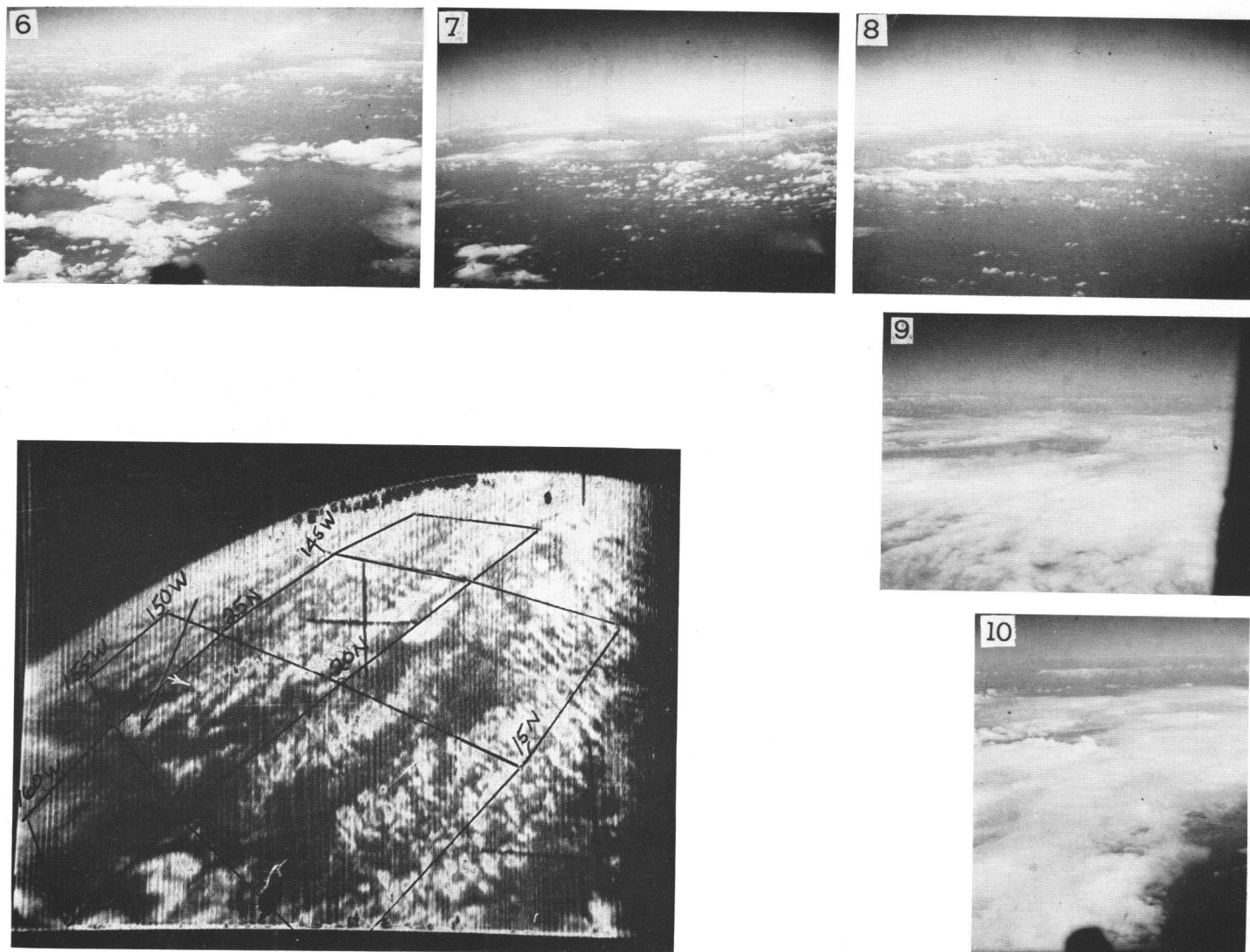


FIGURE 12.—TIROS IV, orbital pass 1543, 0139 GMT, May 27, 1962 and jet pictures 6 through 10, altitude 31,000 ft. Long arrow depicts flight path, short arrow, looking south, points to a region of banded stratocumulus clouds in which some towering cumulus may be seen as shown in jet pictures 9 and 10.

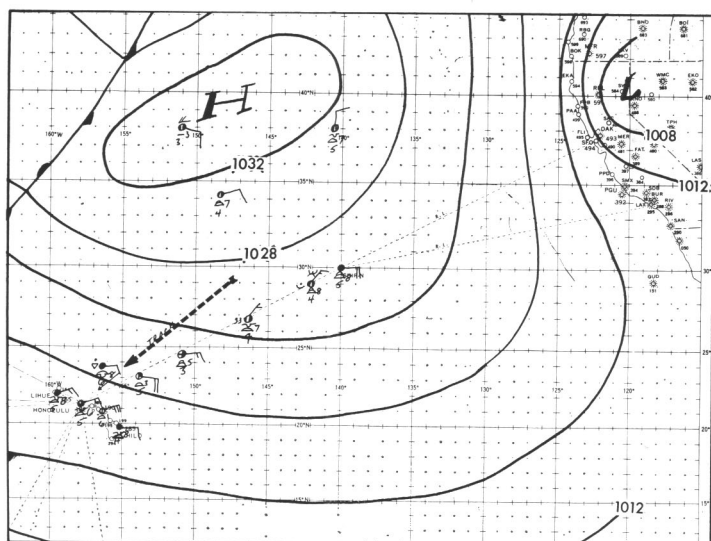


FIGURE 13.—Surface chart, 0000 GMT, May 27, 1962.

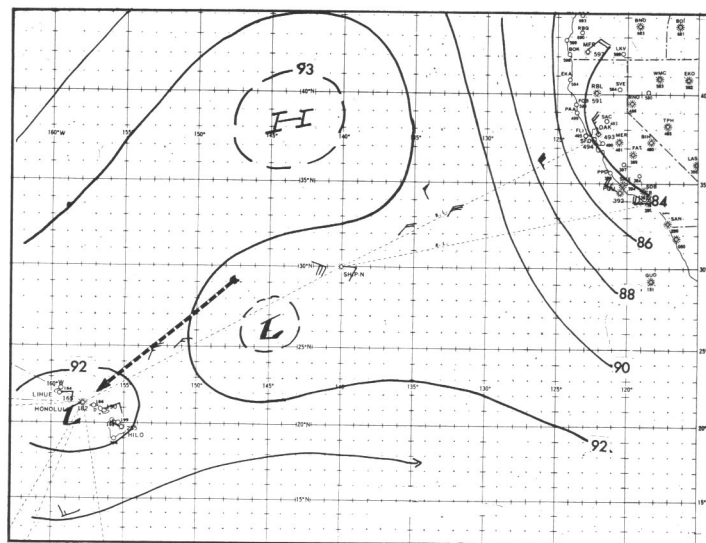
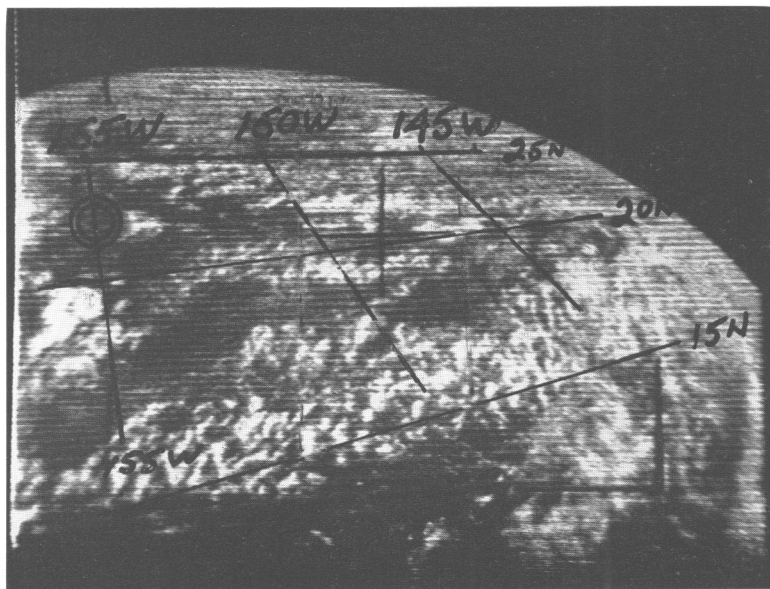


FIGURE 14.—500-mb. chart, 0000 GMT, May 27, 1962.



FIGURE 15.—TIROS IV, orbital pass 1543, 0139 GMT, May 27, 1962 and jet pictures 12, 13, and 14, altitude 31,000 ft. Circled area shows region of scattered fair-weather cumulus shown in accompanying jet pictures.



The synoptic data suggest another source of information. Terrain certainly plays an important part and yet over ocean areas there is no change of surface elevation. Hubert [8] found that differential heating was suggested, and determined that over the Gulf Stream a good relation exists between cloud patterns and surface heating; clouds appear along lines where water temperature is 5°F . warmer than the air. We concur in the conclusion of the Cloud Conference of 1958 [9] that in investigation and use of high altitude pictures caution must be exercised not to force cloud systems to conform rigidly to presently accepted synoptic models; nor should past experience and present knowledge be abandoned by discarding the accepted models. Further, since satellite pictures present information in an entirely new form, the meteorologist will have to develop a new, or at least a modified, language.

Finally, it is suggested that a start be made in compiling a catalog of cloud pictures taken from jet aircraft for comparison with TIROS pictures, taken simultaneously, of the same area. It is felt that pilots and meteorologists may find such a catalog useful, pilots for flight planning and meteorologists for subjective synoptic studies and aid in preparing terminal forecasts.

ACKNOWLEDGMENTS

The writer wishes to express his gratitude to Mr. Joseph Vederman, Chief Airport Meteorologist, WBAS Honolulu, for his encouragement and help in the preparation of this paper, as well as to Mr. L. F. Hubert and Mr. L. W. Tourville of the National Meteorological Satellite Center—the latter for his assistance in cloud interpretation while on temporary detail at WBAS Honolulu.

Thanks are also due to Mr. R. L. Lavoie, Assistant Professor of Meteorology, University of Hawaii, for his guidance and to Lt. Col. J. Sadler, Meteorological Research Laboratory, AFCRL (on assignment with the University of Hawaii) for his views and comments.

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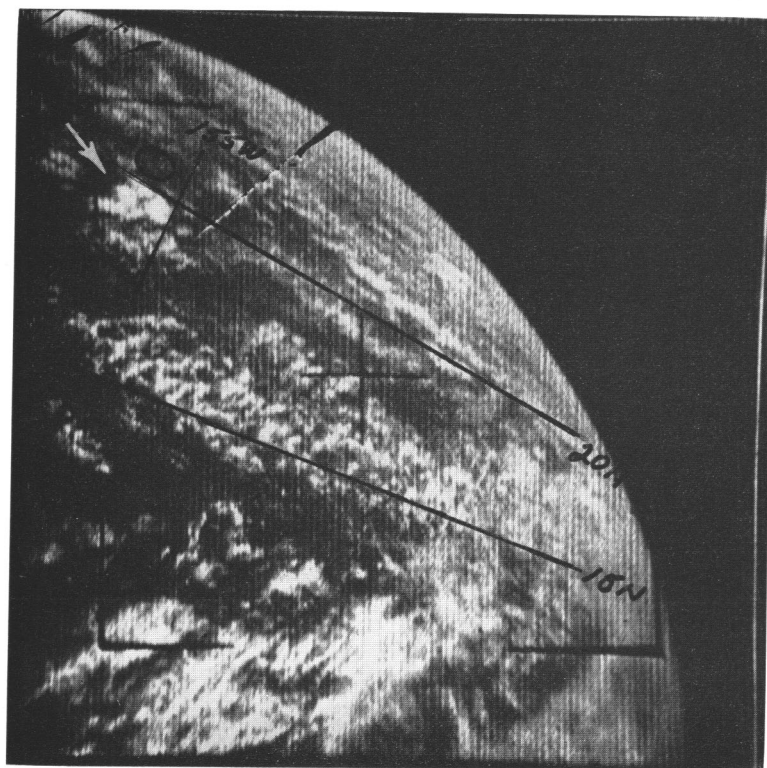


FIGURE 16.—TIROS IV, orbital pass 1543, 0139 GMT, May 27, 1962 and jet pictures 15, 16, and 17, descending from 31,000 ft. Arrow points to cloud-enshrouded island of Hawaii over which some towering cumuli are visible as shown in jet pictures 15 and 16. Circled area shows region of fair-weather cumulus in foreground of accompanying jet pictures.

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[Received July 18, 1963; revised October 7, 1963]